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Commentary

A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values

Charlotte L.R. Payne [a, b, *], Peter Scarborough [b], Mike Rayner [b], Kenichi Nonaka [a]

[a] Department of Intercultural Studies, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima-ku, Tokyo, 171-8501, Japan
[b] Nuffield Department of Population Health, University of Oxford, Rosemary Rue Building, Old Road Campus, Headington, Oxford, Oxon, OX3 7LF, United Kingdom

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ABSTRACT

Background: Edible insects have been proposed as a more environmentally sustainable and nutritious alternative to conventional livestock. In response to the promotion of insects as food and feed by the Food and Agriculture Organization of the United Nations, insect agriculture is now a growing industry across the world. Yet information regarding the nutritional composition of commercially available insect species is disparate in terms of data quality, the location of published sources, and the form in which data is presented.

Scope and approach: We conducted a systematic review of all published nutrient composition data for twelve selected species of commercially available edible insect. Our objective was to create a nutrient composition table in line with INFOODS/EuroFIR guidelines, and to present the results in a standardised form that is easily comprehensible for nutritionists and policy-makers.

Key findings and conclusions: Our results expose the low quality of data describing edible insect nutritional composition, when compared to INFOODS/EuroFIR recommendations. This calls attention to the need for greater adherence to international guidelines in this field. The data that were included in our final table show clear within-species variation in the proportion of both macro- and micronutrients. This highlights the importance of external factors such as feed and ecology in determining nutrient composition.

1. Introduction

In response to growing concerns about the future of world food security, insects have been highlighted as a food source that may address environmental, economic and health concerns as the global population continues to rise (Godfray et al., 2010; Premalatha, Abbasi, Abbasi, & Abbasi, 2011). The biomass of several wild-harvested insect species is already sufficient for commercial supply (Hanboonsong, Jamjanya, & Durst, 2013), while others are intensively farmed both at household level (Hope, Frost, Gardiner, & Ghazoul, 2009) and on an industrial scale (Vantomme, Munke, Van Huis, Van Itterbeeck & Hakman, 2014). Insect foods have recently become available in the US and Europe, and efforts are underway to increase the production of edible insects in developing countries (Vantomme et al., 2014).

Unlike traditional livestock, standardised information about the nutritional composition of commercially available edible insects is limited and inconclusive (Belluco et al., 2013; Rumpold & Schluter, 2013; Vantomme et al., 2014), yet these limited data are increasingly used to justify generalised claims about the health benefits of a particular genus, order or even insects as a single homogenous food category (Dossey, 2013; Holbrook, 2013; Vantomme et al., 2014). Non-systematic reviews have collated data on as many species consumed by humans for which nutritional information could be found, and conclude that while many edible insects are high in nutrients considered essential or desirable for human nutrition (Belluco et al., 2013; Bukkens, 1997; Rumpold & Schluter,

* Corresponding author. BHF CPNP, New Richards Building, Nuffield Department of Population Health, University of Oxford, Rosemary Rue Building, Old Road Campus, Headington, Oxford, Oxon, OX3 7LF, United Kingdom.
E-mail addresses: charlotte.payne@gmail.com (C.L.R. Payne), peter.scarborough@dph.ox.ac.uk (P. Scarborough), mike.rayner@dph.ox.ac.uk (M. Rayner), nonaka@rikkyo.ac.jp (K. Nonaka).

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2013), insects are varied in composition and should not be considered nutritionally equivalent to traditional livestock or sea foods (Raubenheimer, Rothman, Pontzer, & Simpson, 2014). The summary report of the first conference on insects as food and feed stated that insects have 'good nutritional quality' (Vantomme et al., 2014). In peer-reviewed published literature, insects have been advocated as a serious alternative to conventional meat production, both as animal feed and as human food (Paoletti, 2005; Ramos-Elorduy, 1997; Van Huis, 2013). Investments by NGOs, governmental bodies and private companies have facilitated the promotions of small scale farming of edible insects in several African and Southeast Asian countries, where it is hoped that this will result in improved livelihoods and elevated nutritional status (Durst, Johnson, Leslie, & Shono, 2010; Hanboonsong et al., 2013; Hope et al. 2009). Nevertheless, a great deal about the relationship between insect consumption and health status remains unknown. High quality data on nutritional composition is a crucial first step towards understanding this relationship, and is also important to professionals concerned with domestic animal and zoological nutrition.

1.1. Research objectives

For this review, our primary research objective was to collect nutrient composition data systematically for twelve insect species that were selected because they are currently commercially available in several countries throughout Europe, Africa, Southeast Asia, Oceania and North and South America. We applied the INFOODS/EuroFIR guidelines for quality when extracting data from original published sources. These guidelines have been developed to assess the quality of individual values for food components. They are applied to original data on nutrient composition, before this data is aggregated to inform nutrient composition tables. They are designed to ensure that certain standards are observed with regard to the quality of included data, based on seven criteria covering the transparency of the descriptions and identifications of foods, as well as the sampling plan, handling and quality of analysis. Assessing sources of data according to these guidelines is a crucial part of the EuroFIR generic flowchart of the process for compiling a food composition table (Westenbrink, Oseredczuk, Castanheira, & Roe, 2009). The guidelines have been developed based on several national systems for data quality assessment (Oseredczuk & Westenbrink, 2013). In collating data on the nutrient composition of these species, and reporting on the quality of published data, we hope to facilitate species-specific consideration of the potential of insects as a food source and to inform the methodology that is employed in further studies of nutritional composition. In presenting the data as values that are standardised to "per 100 g edible portion on fresh weight basis (EP)", we intend to make our results easily comprehensible for policy-makers and nutritionists alike.

1.2. Selection of species

The species selected for inclusion were a subset of edible insects currently commercially available worldwide, ranging from those that are harvested from the wild in rural areas, to those species that are commercially produced on an industrial scale. The sample also included insects from each of the 'Big Five' (McGrew, 2001) consumed by humans and other primates — Coleoptera, Hymenoptera, Isoptera, Lepidoptera and Orthoptera — as well as one representative of Diptera, as several species from this order are now bred for human and animal consumption (Van Huis, 2013). In the case of insects that are harvested from the wild, identification is limited to the genus level. Two species were selected within each of the following six categories:

1. Species that are gathered from the wild and sold commercially as human food: *Vespula* spp. (Southeast Asia) (Durst et al., 2010), *Macrotermes* spp. (Sub-Saharan Africa (Van Huis, 2003);
2. Agricultural pest species that are traditionally harvested for human consumption: *Encosternum* spp. (Southeast Asia (野中, 2008), Sub-Saharan Africa (Dzerefos, Witkowski, & Toms, 2013)), *Oxya* spp. (Southeast Asia (Mitsuhashi & Paoletti, 2005));
3. Traditionally wild-gathered species that are sold commercially as food, for which farming methods are currently being developed: Rynchophorus phoenicus. (Australasia, Southeast Asia, Sub-Saharan Africa, South America, (Bukkens, 1997; Hanboonsong et al., 2013)), Oecyphylla smaragdina (Southeast Asia, (Van Itterbeeck, Sivongxay, Praxaysombath, & van Huis, 2014))
4. Species that are successfully reared on a large scale and sold commercially both for export and domestic consumption: *Acheta domesticus* (Southeast Asia, Europe, North America, Sub-Saharan Africa, (Collavo et al., 2005; Hanboonsong et al., 2013; Vantomme et al., 2014)); *Gonimbrasia bellina* (Sub-Saharan Africa, (Hope et al., 2009));
5. Species with a long history of domestication by humans for their by-products, and also sold commercially as food: *Apis mellifera*, *Bombyx mori* (Chen et al., 1998);
6. Species not traditionally consumed by humans that are currently farmed on a large scale and intended for use as food and feed: *Tenebrio molitor*, *Hermetia illucens* (Rumpold & Schlüter, 2014)

Where genera, rather than specific species, are selected, this is because these genera represent a suite of generalist species that are wild-harvested across a wide geographical area. Where species within these genera were specified in peer-reviewed publications, these were confirmed as human-consumed species using the Wageningen list of edible insects of the world (Jongema, 2014).

1.3. Search strategy

We aimed to compile high quality nutrient composition data from three sources: Published research articles, official online nutrient composition databases and commercial suppliers.

To identify published research articles, we searched five databases (Web of Science, Medline, Global Health, CAB Abstracts and EMBase) using the following search entry for each of the twelve species:

> (*Genus and/or species name*) AND ((edible OR edible insect OR entomophagy OR food OR feed) AND (nutrition* OR protein* or fat* OR mineral* OR vitamin*))

To identify data available in official nutrient composition tables, we searched the food composition tables available on the FAO INFOODS website (FAO INFOODS, 2014) for inclusion of the twelve selected edible insect species.

To identify commercial suppliers we conducted two Google searches: The first used the search term 'edible insects' and the second 'livefoods insects', as some of the species selected are also sold as reptile feed. We contacted every supplier listed in the first ten hits for each search, requesting nutrient composition data for one or more of the selected species.

1.4. Inclusion/exclusion criteria

To achieve a standardised comparison of unprocessed insect foods, we excluded datalines that did not comply with the following criteria for food description: